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Holmium:YAG Laser Prostatectomy Canine Feasibility Study

John N. Kabalin, MD

Urology Laboratories, Palo Alto Veterans' Affairs Medical Center, and Department of Urology, Stanford University School of Medicine, Stanford, California 94305

Background and Objective: Laser coagulation prostatectomy performed with the Neodymium:Yttrium-Aluminum-Garnet laser has emerged as a viable alternative for the treatment of benign prostatic hyperplasia. Laser vaporization prostatectomy, if feasible, has the potential to reduce postoperative catheterization time and achievement time of maximum voiding outcomes. The objective of this study was to determine the ability of the Holmium:Yttrium-Aluminum-Garnet laser wavelength to vaporize prostatic tissue and create an immediate prostatectomy defect.
Study Design/Materials and Methods: The Holmium:Yttrium-Aluminum-Garnet laser was applied in vivo in a canine prostate model. Laser energy was delivered endoscopically via quartz laser fibers circumferentially to each prostatic fossa. High energies, up to 2.8 joules per pulse and 60 watts total power, were utilized. All prostates were surgically removed immediately following laser applications to determine acute laser effects.
Results: Immediate tissue ablation or vaporization with this laser wavelength was found to be both feasible and relatively efficient. The mean transverse dimension of the prostatic defects produced was 19 mm, with a maximum transverse dimension of 27 mm. In one prostate a cavity of 27 (transverse) by 29 (anterior-posterior) by 43 (length) mm was created, with an estimated tissue removal of ~ 20 cc. Hemostasis with the Holmium laser was adequate in this canine prostate model. In addition to the acute tissue cavity created, a 1–2 mm rim of surrounding tissue coagulation was observed in each specimen.
Conclusion: The Holmium:Yttrium-Aluminum-Garnet laser wavelength is capable of acute prostatic tissue vaporization and deserves ongoing study with potential application in the surgical treatment of benign prostatic hyperplasia in men.

Key words: benign prostatic hyperplasia, dogs, Holmium:YAG, laser surgery, prostate, prostatectomy

INTRODUCTION

Laser prostatectomy has emerged as a viable and valuable surgical technique for the management of bladder outlet obstruction due to benign prostatic hyperplasia in men [1–5]. To date, these procedures have relied predominantly on the Neodymium:Yttrium-Aluminum-Garnet (Nd:YAG) laser. At 1,064 nanometers, this wavelength is poorly absorbed by water, penetrates deeply into tissue, and with the prolonged, high energy applications currently utilized, produces deep coagulation necrosis of the treated prostate. This is a remarkably hemostatic and nonmorbid approach to prostatectomy, and even patients who are systemically anticoagulated have been treated safely [6–7]. However, this "laser coagulation prostatectomy" produces significant local

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Address reprint requests to John N. Kabalin, M.D., Chief, Urology Section 122C, V.A. Medical Center, 3801 Miranda Avenue, Palo Alto, CA 94304.

tissue edema with minimal acute tissue loss, resulting in a typical postoperative catheterization requirement of several days. Thereafter, the coagulated prostatic tissue sloughs gradually over several weeks, and it is only gradually over the same extended time period that patients experience significant clinical improvement in voiding parameters.

If prostatic tissue could be removed immediately during prostatectomy, while still maintaining the hemostasis and minimal morbidity offered by existing laser coagulation techniques, the promise of drastically shortened postoperative recovery times looms large. "Laser vaporization prostatectomy" has been attempted with the Nd: YAG laser, utilizing high energy density beams and high power treatments through 60–100 watts [8,9]. However, by its very nature, this wavelength is a very poor tissue vaporizer, and coagulation effects predominate. By contrast, with a wavelength of 2,140 nanometers, the Holmium: Yttrium-Aluminum-Garnet (Ho:YAG) laser is highly absorbed by water and produces significant acute tissue vaporization. The applicability and feasibility of using this wavelength to perform laser prostatectomy are examined in the present study.

MATERIALS AND METHODS

Five adult male dogs, ages 1.5–10 years (mean 5.7 years), weighing 14–32 kilograms (mean 22 kg), underwent Ho:YAG laser irradiation of the prostate. Dogs were anesthetized with 25 mg/kg intravenous sodium thiamylal followed by 1–2% halothane by inhalation. A lower vertical midline abdominal incision was then made sharply and the dome of the bladder exposed and elevated into the wound. A small cystotomy was made in the bladder dome and a standard 20 French cystoscope advanced into the prostatic urethra in an antegrade fashion. At the same time, an open-ended, 8 French silastic catheter was passed retrograde through the urethra and placed just distal to the veru montanum in the prostatic urethra. This catheter was left to gravity drainage and allowed continuous flow of room temperature water irrigation during each procedure.

A 400, 600, or 1,000 μm Ho:YAG quartz delivery fiber was passed into the prostatic fossa through the working port of the cystoscope and all laser treatments performed under direct vision. Both straight end-firing fibers and side-firing Ho: YAG fibers with a distal polished quartz internal reflection mechanism (product of Coherent Medical Group)—emitting a beam with an approximate 70° angle of incidence and a 30° angle of divergence—were utilized. A 600-μm, side-firing Ho:YAG fiber with these beam characteristics was found most suitable to this application. A pulsed Ho:YAG laser source (VersaPulse Select, Coherent Medical Group) capable of 60 watts of power output was utilized. Pulse energies between 1.0 and 2.8 joules were selected, settling on 2.8 joules (maximum output) for the majority of treatments. Treatments were begun just distal to the seminal colliculus in the dogs and continued proximally to the bladder neck. Typically, the Ho: YAG fiber was moved slowly along the length of the prostatic urethra in contact or near contact with tissue. This was repeated circumferentially until the entire prostatic fossa was ablated, or in one case, one-half or one lateral lobe was treated. Up to 116,500 joules of Ho:YAG energy were delivered in a single prostate during a 90-minute procedure.

All dogs were sacrificed acutely and prostates surgically removed for examination. Post-treatment prostatic weights ranged from 12.4 to 50.7 grams (mean 26.7 grams). Prostates were sectioned transversely for gross examination of acute laser effects and prostatectomy defects measured in three dimensions.

RESULTS

Endoscopic prostatic tissue ablation with a high energy, free beam Ho:YAG laser was found to be both feasible and relatively efficient. Significant tissue loss and sizeable prostatectomy defects were produced acutely (Figs. 1–4). The mean transverse dimension of the prostatic defects produced was 19 mm, with a maximum transverse dimension of 27 mm. In one prostate a cavity measuring 27 mm (transverse) by 29 mm (anterior-posterior) by 43 mm (length) was created, with an estimated tissue removal of ~ 20 cc calculated ($\pi/6 \cdot$ transverse $\cdot$ anterior-posterior $\cdot$ length). Hemostasis with the Ho:YAG laser was found to be adequate in this canine prostate model. In addition to the acute tissue cavity created, a 1–2 mm rim of surrounding tissue coagulation was observed in each specimen, clearly demarcated by a rim of surrounding tissue hemorrhage, similar to

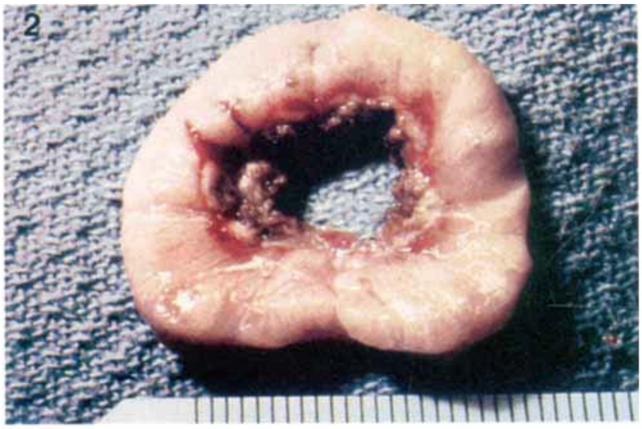

Fig. 1. Transverse section through prostate immediately following left lateral lobe transurethral Ho:YAG laser irradiation, (sections displayed as open book, proximal on left, distal on right). The left lateral lobe has been vaporized. Note also the 1–2 mm rim of pale coagulated tissue demarcated by a rim of hemorrhage, which surrounds the vaporization defect produced by the Ho:YAG.

Fig. 2. Transverse section through prostate immediately following circumferential transurethral Ho:YAG irradiation. A symmetrical prostatectomy defect has been produced.

Fig. 3. Transverse sections through prostate immediately following aggressive transurethral Ho:YAG irradiation (sections displayed as open book, proximal on left, distal on right), carrying laser vaporization to level of prostatic capsule in one location.

Fig. 4. Transverse section through prostate immediately following circumferential transurethral Ho:YAG irradiation. A large round prostatectomy defect, estimated 20 cc total volume, has been produced by Ho:YAG laser vaporization.

prior laser coagulation effects documented in the canine prostate [10–12] and confirmed by histologic examination of standard hematoxylin and eosin stained tissue sections.

DISCUSSION

The introduction of the Ho:YAG laser wavelength into urologic surgical practice has been relatively recent, pioneered by Douglas Johnson and associates, whose earliest reports date only to 1992 [13–14]. Various soft tissue applications, including partial nephrectomy and pelvic lymphadenectomy in animal models, have been described. Johnson [15] reported successful Ho:YAG treatment of superficial bladder carcinoma in humans in 1994. At lower pulse energies, the Ho:YAG provides a precise and effective instrument for soft tissue incision, with potential applications in the treatment of urethral and ureteral strictures, including ureteropelvic junction obstructions. Ho:YAG laser lithotripsy for urinary calculi has also been described [16].

Johnson and associates [14] reported the

first prostatic application of the Ho:YAG laser in 1992. In a canine model, the Ho:YAG laser was used to perform prostatic incision. Limited by existing Ho:YAG instrumentation at that time, they treated with no more than 1.0 joule pulse energies at a maximum power of 15 watts. This was delivered through a rigid delivery device passed alongside a cystoscope through a separate cystotomy. Although these incisional applications produced minimal tissue ablation, Johnson and colleagues [14] reported the procedures as "technically precise, easy, and safe," while observing "no significant bleeding." This report also provides detailed pictorial documentation of histologic changes following Ho:YAG application in the canine prostate, including a narrow zone of tissue coagulation seen surrounding the laser incision sites, and observations of complete re-epithelialization of all incisions by 3 weeks posttreatment.

Using modern Ho:YAG technology at very high pulse energies and total power settings, delivered via small caliber flexible quartz delivery fibers that can be used through a standard cystoscope, the present study attempted for the first time to perform a definitive laser vaporization prostatectomy, entailing acute ablation of significant amounts of prostatic tissue to create an immediate cavity or so-called prostatectomy defect. This study demonstrates that such an endeavor is both feasible and practical. In addition, confirming prior observation by Johnson and associates [14], the tissue ablation produced by the Ho:YAG proceeded with adequate hemostasis in this canine prostate model. The latter is obviously a key concern in maintaining a low morbidity profile in any future human clinical applications.

Ongoing laboratory and clinical examination of the Ho:YAG laser for urologic surgical use is clearly indicated. In particular, based on the present findings, this wavelength deserves study of its potential application in the surgical treatment of benign prostatic hyperplasia in men.

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REFERENCES

1. Costello AJ, Bowsher WG, Bolton DM, Braslis KG, Burt J. Laser ablation of the prostate in patients with benign prostatic hypertrophy. Br J Urol 1992; 69:603–608.
2. Kabalin JN. Laser prostatectomy performed with a right angle firing Neodymium:YAG laser fiber at 40 watts power setting. J Urol 1993; 150:95–99.
3. Norris JP, Norris DM, Lee RD, Rubenstein MA. Visual laser ablation of the prostate: Clinical experience in 108 patients. J Urol 1993; 150:1612–1614.
4. Leach GE, Sirls L, Ganabathi K, Roskamp D, Dmochowski R. Outpatient visual-assisted prostatectomy under local anesthesia. Urology 1994; 43:149–153.
5. Shanberg AM, Lee IS, Tansey LA, Sawyer DE. Extensive Neodymium:YAG photoirradiation of the prostate in men with obstructive prostatism. Urology 1994; 43:467–471.
6. Kabalin JN, Gill HS. Urolase laser prostatectomy in patients on warfarin anticoagulation: A safe treatment alternative for bladder outlet obstruction. Urology 1993; 42:738–740.
7. Bolton DM, Costello AJ. Management of benign prostatic hyperplasia by transurethral laser ablation in patients treated with warfarin anticoagulation. J Urol 1994; 151: 79–81.
8. Fournier GR, Jr, Narayan P. Factors affecting size and configuration of Neodymium:YAG (Nd:YAG) laser lesions in the prostate. Lasers Surg Med 1994; 14:314–322.
9. Narayan P, Fournier GR, Jr, Indudhara R, Leidich R, Shinohara K, Ingerman A. Transurethral evaporation of prostate (TUEP) with Nd:YAG laser using a contact free beam technique: Results in 61 patients with benign prostatic hyperplasia. Urology 1994; 43:813–820.
10. Johnson DE, Price RE, Cromeens DM. Pathologic changes occurring in the prostate following transurethral laser prostatectomy. Lasers Surg Med 1992; 12:254–263.
11. Kabalin JN, Gill HS. Dosimetry studies utilizing the Urolase right angle firing Neodymium:YAG laser fiber. Lasers Surg Med 1994; 14:145–154.
12. Gill HS, Kabalin JN, Mikus PW. Characterization of tissue effects produced by the ProLase II lateral-firing Neodymium:YAG laser fiber in the canine prostate. Lasers Surg Med 1994; 15:185–190.
13. Johnson DE, Cromeens DM, Price RE. Use of the Holmium:YAG laser in urology. Lasers Surg Med 1992; 12: 353–363.
14. Johnson DE, Cromeens DM, Price RE. Transurethral incision of the prostate using the Holmium:YAG laser. Lasers Surg Med 1992; 12:364–369.
15. Johnson DE. Use of the Holmium:YAG (Ho:YAG) laser for treatment of superficial bladder carcinoma. Lasers Surg Med 1994; 14:213–218.
16. Sayer J, Johnson DE, Price RE, Cromeens DM. Ureteral lithotripsy with the Holmium:YAG laser. J Clin Laser Med Surg 1993; 11:61–65.